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UNITED STATES
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BUREAU OF MINES
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INFORMATION CIRCULAR

SUSPENSION ROOF SUPPORT

PROGRESS REPORT 1

BY

EDWARD THOMAS, A. J. BARRY, AND ARTHUR METCALFE

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SUSPENSION ROOF SUPPORT[1]

Progress Report 1

By Edward Thomas[2], A. J. Barry[3], and Arthur Metcalfe[4]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Inf. Circ. 7533."

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INTRODUCTION

Early in 1947 the Bureau of Mines became interested in adapting suspension roof support to coal mining[5] as a possible means of reducing the high rate of accidents from falls of roof. For a time the program made little progress because of the shortage of steel products after the end of World War II, but during the past 8 months this restriction has eased, and as of May 1, 1949, 114 mines had either started experimental work or had ordered materials and equipment in anticipation of trial installations. It is estimated that 30 linear miles of roof in underground passageways have been secured by this method in recent months, and no lost-time roof-fall accident has been reported in these areas up to that date.

Many coal-mining companies in widely separated localities have cooperated in making experimental installations. In very few instances are these companies entirely satisfied that they have arrived at the best solution in determining the most efficient adaptation to suit their particular conditions. Moreover, new ideas and modifications of the basic principle are constantly being brought to light and are being tested. Available test data is far from complete, and it is conceivable that some new idea will be developed to alter the present concept of proper technique; therefore, this progress report does not attempt to answer all questions that might arise in connection with this method of roof support; it simply recounts the experience acquired to date. Consequently, few references to costs are made. Up-to-date quotations on material and equipment used in suspension roof-support installations may be obtained from numerous mine-supply companies.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation of mining companies whose personnel made possible collection of the information contained in this circular: Bethlehem Collieries Corp., Barrackville, W. Va.; Berwind-White Coal Mining Co., Windber, Pa.; Consolidation Coal Co., (Ky.); Jenkins, Ky.; Consolidation Coal Co. (W. Va.), Fairmont, W.Va.; Clinchfield Coal Corp., Dante, Va.; Consolidated Coal Co., St. Louis, Mo.; Hanna Coal Co., St. Clairsville, Ohio; Missouri Portland Cement Co., Sugar Creek, Mo.; Pocahontas Fuel Corp., Pocahontas, Va.; Reppert Coal Co., Dola, W. Va.; St. Joseph Lead Co., Bonne Terre, Mo.; and Tennessee Coal, Iron, & Railroad Co., Birmingham, Ala.

GENERAL

The fundamental theory of suspension roof supports is not new; in fact, its application in the construction of beams predates mining itself. The basic principle involved is the reinforcement of roof rock with steel rods inserted in the roof and anchored therein at points where the rock is least likely to be affected by stresses resulting from mining. Such roof supports have been used in mines for many years in widely separated localities. The St. Joseph Lead Co., operating in southeastern Missouri, apparently was the first large mining company to prove the practicability of the principle by applying it in a systematic manner for securing roof for more than 20 years (fig. 1).

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[5] Thomas, E., Seeling, C. H., Perz, F., Hansen, M. V., Control of Roof and Prevention of Accidents From Falls of Rock and Coal: Bureau of Mines Inf. Circ. 7471, 1948, pp. 8-9.

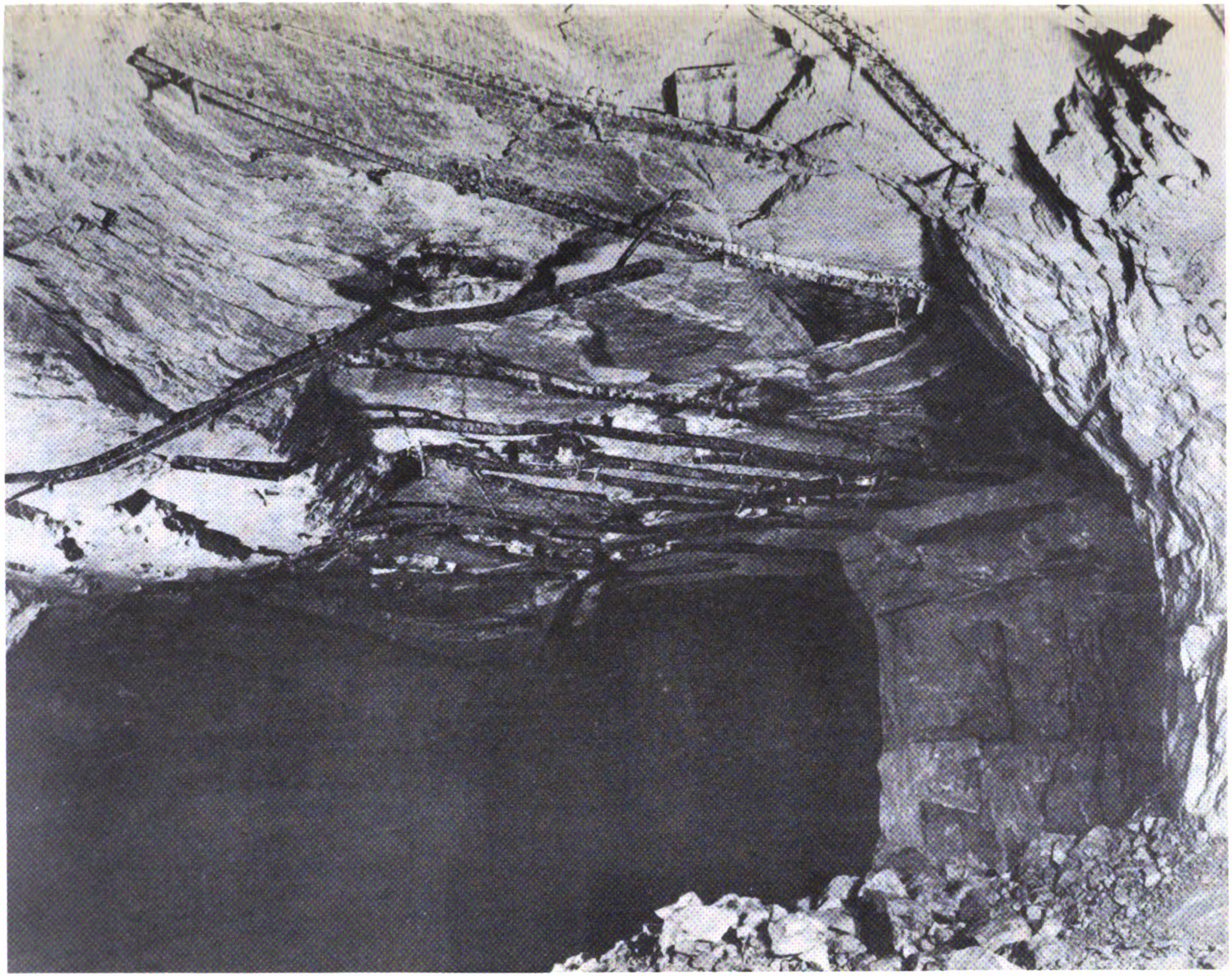

Figure 1. - Suspension support installation (St. Joseph Lead Co.).

Possibly the reason for the delay in acceptance by the "practical miner" was that the method appears at first glance to approximate "holding one's self up by one's bootstraps." In fact, in attempting to find a suitable descriptive name for this method of roof reinforcement, in which the roof apparently supports itself instead of being supported by conventional timbering, many persons suggested "sky hooks." Nevertheless, the principle is scientifically sound. Briefly, it involves a method of applying reinforcing material to provide additional beam strength. Roof rocks have planes of weakness owing to thin bedding, cleating, or faulting, which during mining may be bound together to form competent beams across openings.

JUSTIFICATION FOR SUSPENSION SUPPORTS

Depending on previous mining practices at a particular mine, an immediate increase in material cost may occur upon conversion from conventional timbering to the suspension-support method. For this reason, mine operators should be cautioned not to adopt makeshift and potentially unsafe variations of suspension supports without proper preliminary experimental preparation. To justify the greater material cost, some advantages that may be gained if this type of support is installed properly are listed below and all reflect directly or indirectly on the final cost of operation.

With regard to safety, the companies that have experimented with large installations, especially in fully mechanized mines, report the following advantages:

1. A systematic method of support is provided at the working face. In fact, to obtain maximum benefit from the method it is necessary to install the supports within a few inches of the face before cutting the coal, so that flexing of the immediate roof strata is held to the minimum. When this is done, the mining-machine operator, driller, shot firer, and loading-machine operator have adequate protection without using safety posts, which are easily dislodged. Moreover, when the immediate roof is supported rigidly, experience has shown that it is less likely to shatter during blasting.

2. This type of support cannot be dislodged by blasting or moving equipment. A preliminary break-down of roof-fall accident statistics obtained from the Accident Analysis Branch, Bureau of Mines, shows that, in 1946, 14 fatal and 138 nonfatal accidents were attributed directly to the unintentional dislodgment of roof supports.

3. Ventilation is benefited because resistance to the flow of air through mine passageways is reduced. At a certain gassy mine it is necessary to extend line brattice to the face. After conventional timbering was supplanted by suspension roof supports, removal of obstruction behind the brattice increased the volume of air that sweeps the face an average of 15 percent.

4. Cuts of coal are "cleaned up" thoroughly, so that very small amounts remain along roadways to be ground into explosive dust. Thus, indirectly explosion hazards are reduced through the use of suspension supports.

5. Side clearance along roadways is improved by the elimination of timbers; moreover, storing of bulky timber which often obstruct clearance along roadways, is eliminated. In addition, overhead clearance is improved through absence of crossbars. The 1946 record of causes of accidents in coal mines shows 32 fatal and 1,689 nonfatal haulage accidents to persons who were squeezed between moving equipment and cars, ribs, timbers, or roof.

6. Housekeeping in general is improved; storage space for materials is reduced; electric power cables, trailing cables, water and air lines (fig. 2), and brattice cloth are supported with specially designed brackets, which are attached to the suspension-bolt ends.

From the standpoint of efficiency, the suspension roof support affords several distinct advantages:

1. A loading machine can clean up a cut from rib to rib without interference of timber legs. Under most mining conditions, if a cut is shot properly a shoveler or pick man is not required to "clean up" at the face during the loading cycle. Such a pick man ordinarily trims the ribs and face, protected by temporary screw jacks, after the loading machine has completed its work and before the "roof-bolting" crew enters. Although available time-study data are few, it is evident that 15 to 50 percent of the time required to load a cut when the roof is supported by conventional legs and crossbars is saved when loading under suspension supports. One company reports: "Approximately 12 minutes per fall (cut) of coal is saved in loading time by elimination of face timbers and not having to advance crossbars during the loading cycle." Formerly, conventional crossbar sets on 4-foot centers were used at this mine, and it was necessary to stop loading of coal to erect them. At present, the mine has suspension-roof supports consisting of vertical rods 1 inch in diameter, 54 inches long, and with 8- by 8-by 3/8-inch bearing plates on 4-foot centers.

2. A few experiments indicate that in some instances mine openings, especially rooms, can be widened considerably with safety by installing suspension supports, thus reducing drilling and explosives costs and increasing the efficiency of loading machines through reduction of tramming time per ton loaded.

3. Mobile equipment, especially shuttle cars, can be moved faster with greater safety.

4. Usually, the labor cost of installing this type of support will be less than for conventional supports, especially when suspension supports replace conventional wooden cross bars.

5. Ordinarily, suspension supports may be considered permanent. The experience at mines of the St. Joseph Lead Co. and at other operations is that supports installed at the face immediately after the roof is exposed rarely require further attention.

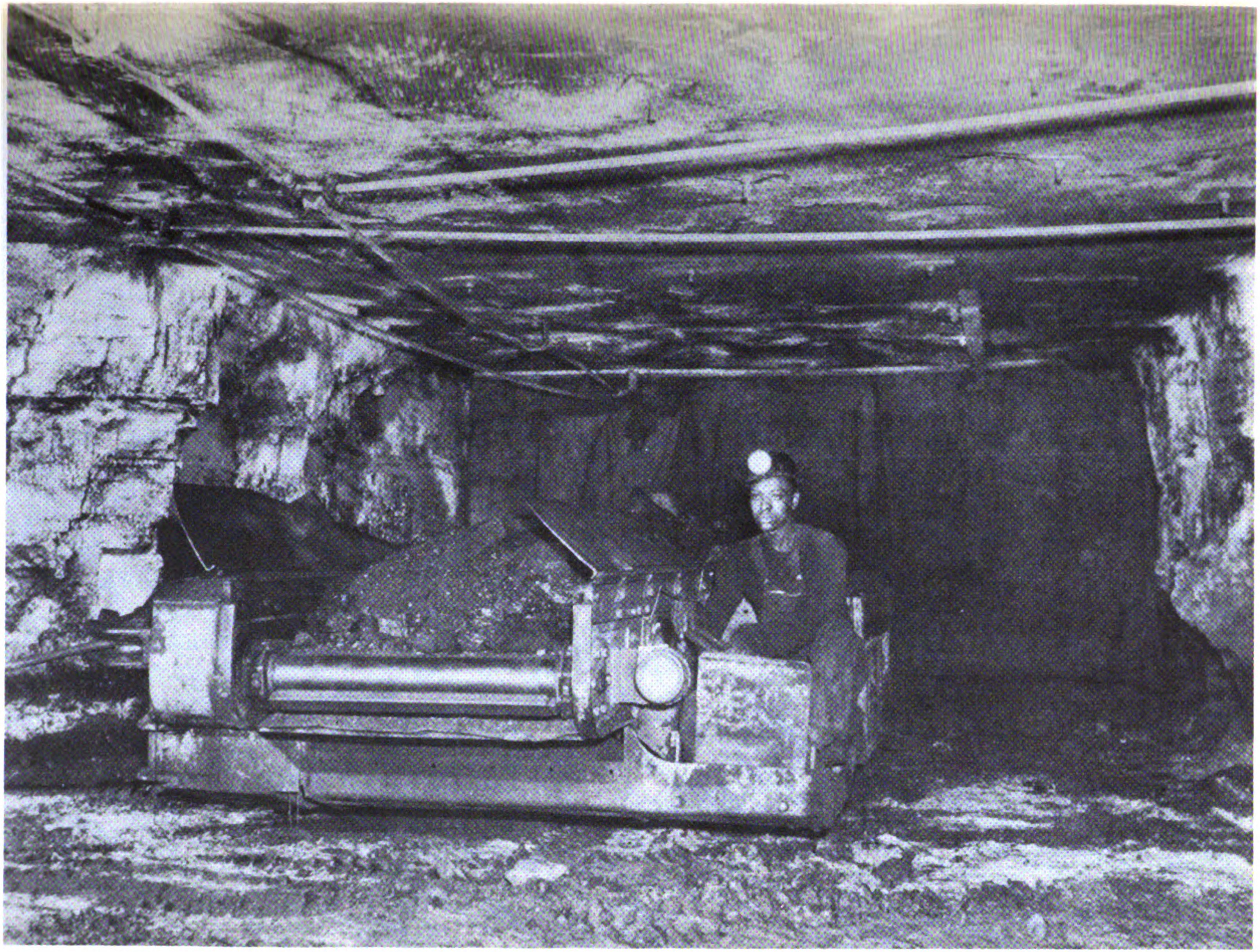

Figure 2. - Shuttle-car haulageway. Water and air lines are readily supported from suspension-bolt ends.

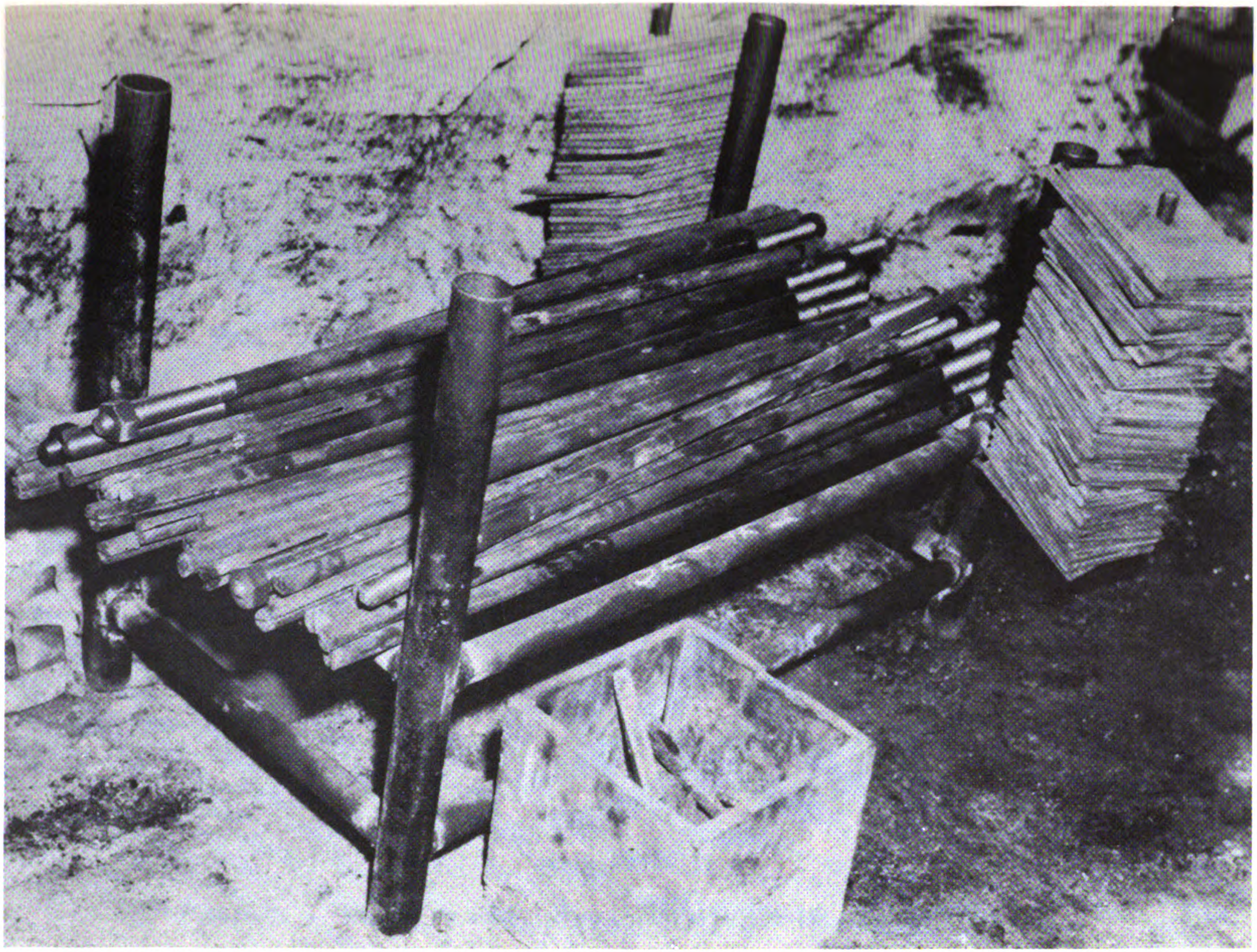

Figure 3. - Underground storage of supplies.

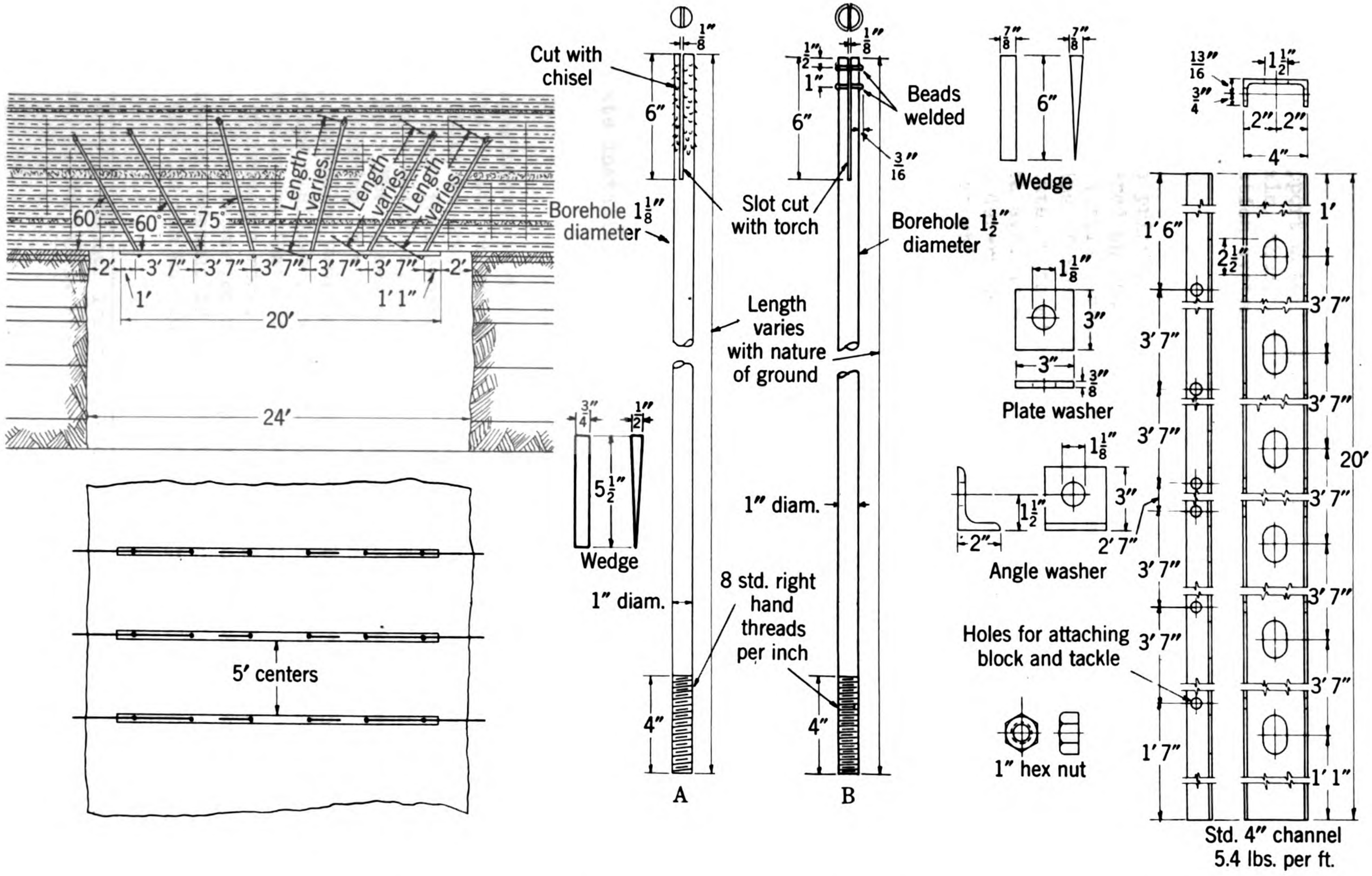

Figure 4. - Suspension roof support installation (St. Joseph Lead Co.).

6. Roof-support materials are much less bulky (fig. 3) than conventional timbering materials; thus, substantial savings accrue through lessened demands on the transportation system.

VARIATIONS IN USE

Although the principle of suspension roof support is basic, each mine should be considered an individual problem when the use of such support is contemplated. Very little investigative work has been done to determine the physical properties of rocks in place, especially the thinly bedded shales and sandstones associated with minable coal beds. In view of the scarcity of physical test data available, it is not now possible to present formulae that can be applied to determine accurately the best anchoring device, the most effective angles at which to install rods, or even the best diameters of drill holes and rods.

The details of present installations have been determined largely by "cut and try" methods based on the appearance of the roof rocks, the difficulties encountered when conventional supports were used, and tools available. Probably future installations will be determined similarly for some time to come. Admittedly, the factor of safety has been as great as could be provided, possibly greater in some installations than is necessary for systematic work. In every Bureau-sponsored installation every precaution has been taken to insure against failure that might cause personal injury.

Many mine equipment manufacturers realize that there is a potential market for suspension roof supports and have designed or are designing new equipment to facilitate installation.

St. Joseph Lead Co. Practice

The experimental work done thus far in other fields has not justified any basic changes in the practice developed by the St. Joseph Lead Co., shown in figure 4. Standard practice for many years (described by Weigel[6]) has been to install 1-inch rods averaging 8 feet in length at an angle on about 4-foot centers along a 4-inch channel bearing plate bent to conform with the immediate roof contours. The bedded dolomitic rock formation has numerous vertical slips that do not conform to a systematic pattern; therefore, the sets are not necessarily installed parallel to one another but so that they cross a maximum number of slips. Single rods fitted with square bearing plates at the mouths of holes usually are installed either at an angle or vertically to support a small area of insecure roof. This type of support is called a "shin plaster." All drilling for suspension roof supports is done with pneumatic percussion drills. Usually, because of the high back (roof), light, hand-held, pneumatic drills are used in conjunction with ratchet-type feed boards or block-and-tackle.

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[6] Weigel, W. W., Channel Irons for Roof Control: Eng. and Min. Jour., vol. 144, No. 5, May 1943, pp. 70-72.

Ordinarily, a suspension support set comprised of a channel and several rods is erected by workmen who are supported on a scaffold or "trapeze." The procedure for erecting is as follows:

1. The foreman determines the limits of the area to be supported. He orders 4-inch channels to be fabricated at the shop, with holes spaced on about 4-foot centers along the length of the channel (fig. 4). If the surface of the roof is uneven, the channel is bent in the shop to conform therewith, and allowance is made to maintain the holes on about 4-foot centers. Any minor irregularities are ignored, because the channel can be bent somewhat when the rods are tightened.

2. Starting in firm roof (near a pillar or other support), a vertical hole is drilled about 6 inches deep, and an eyebolt is secured in the hole by driving an ordinary feather-edged wedge (with a sledge hammer) between the shank of the bolt and the side of the borehole, so that it can be recovered later.

3. The pneumatic drill is attached to a small block-and-tackle, which, in turn, is supported by the eyebolt; thus, a means of support and a feed for the drill is obtained.

4. After the first rod hole is drilled, a threaded driving dolly is attached to the threaded rod head for protection of the threads. The rod then is anchored in the hole by driving it to "refusal" with the pneumatic drill. One end of the channel is then fitted over the protruding end of the rod; the other end of the channel is supported by a timber jack set on the mine floor or on the trapeze. The first rod is secured to the channel with an angle washer and a nut that is tightened with a pneumatic impact wrench.

5. Subsequent boreholes are drilled by using the holes in the channel as a template, and the rods are secured similarly to the first one, except that the block-and-tackle is attached to holes drilled in a flange of the channel (fig. 4).

After drilling each hole and before a rod is anchored therein, the back of the hole is "sounded" by striking it with a steel bar. If the sound is "drummy." the hole is drilled deeper, until firm ground is attained and a longer rod is used.

Other Practices

As stated heretofore, the basic concept is capable of wide variation. Records disclose the use of suspension supports in coal mines in this country as early as 1905; however, because of space limitations and because the adaptations are not in use at present, no attempt is made to list them here. Figures 5 to 9, inclusive, and 11 to 13, inclusive, show several variations in use at present.

In the mines of the Missouri Portland Cement Co. at Sugar Creek, Mo., a method of roof support is used that is quite similar to that of the St. Joseph

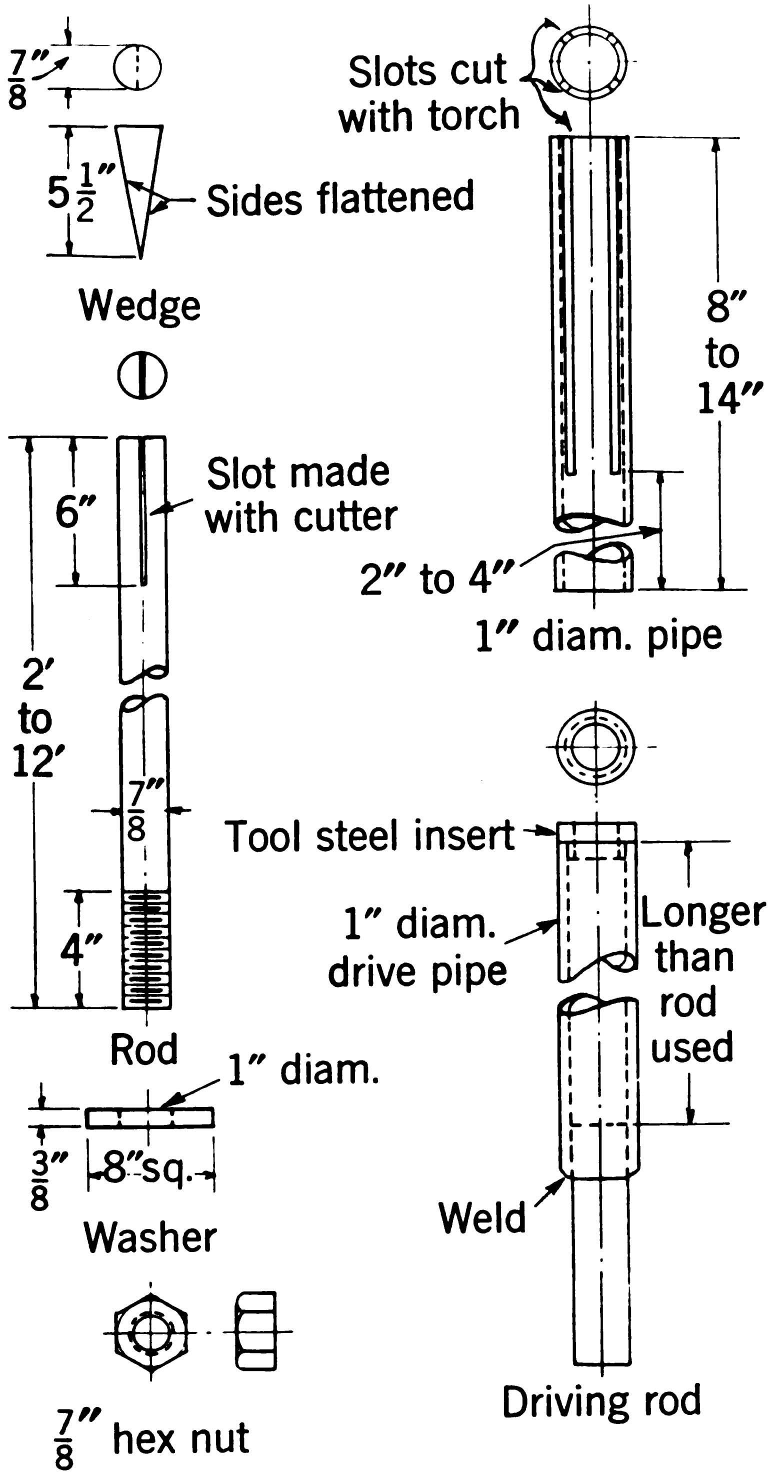

Figure 5. - Anchorage variation (Missouri Portland Cement Co.).

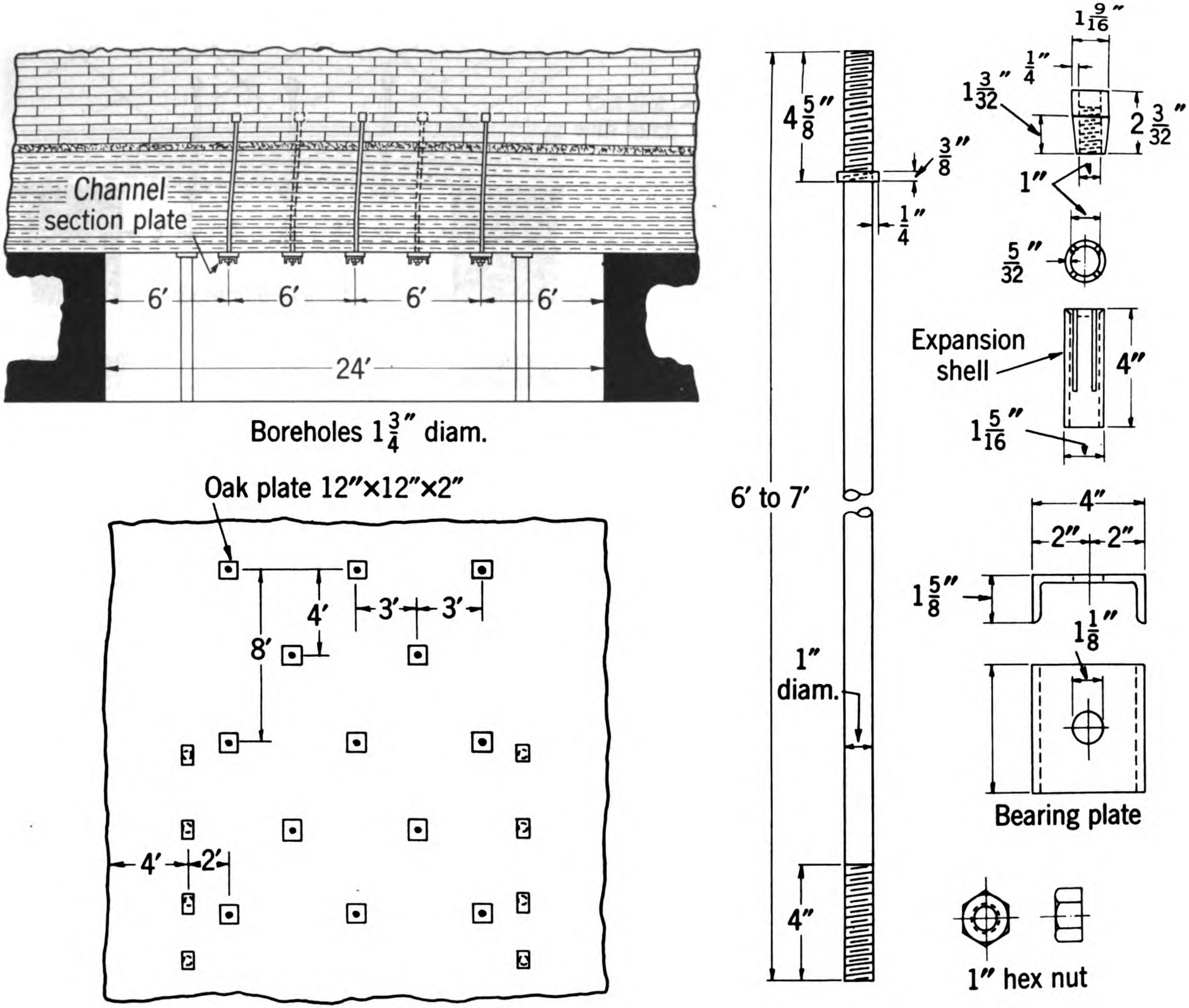

Figure 6. - Expansion hanger method (Consolidated Coal Co.).

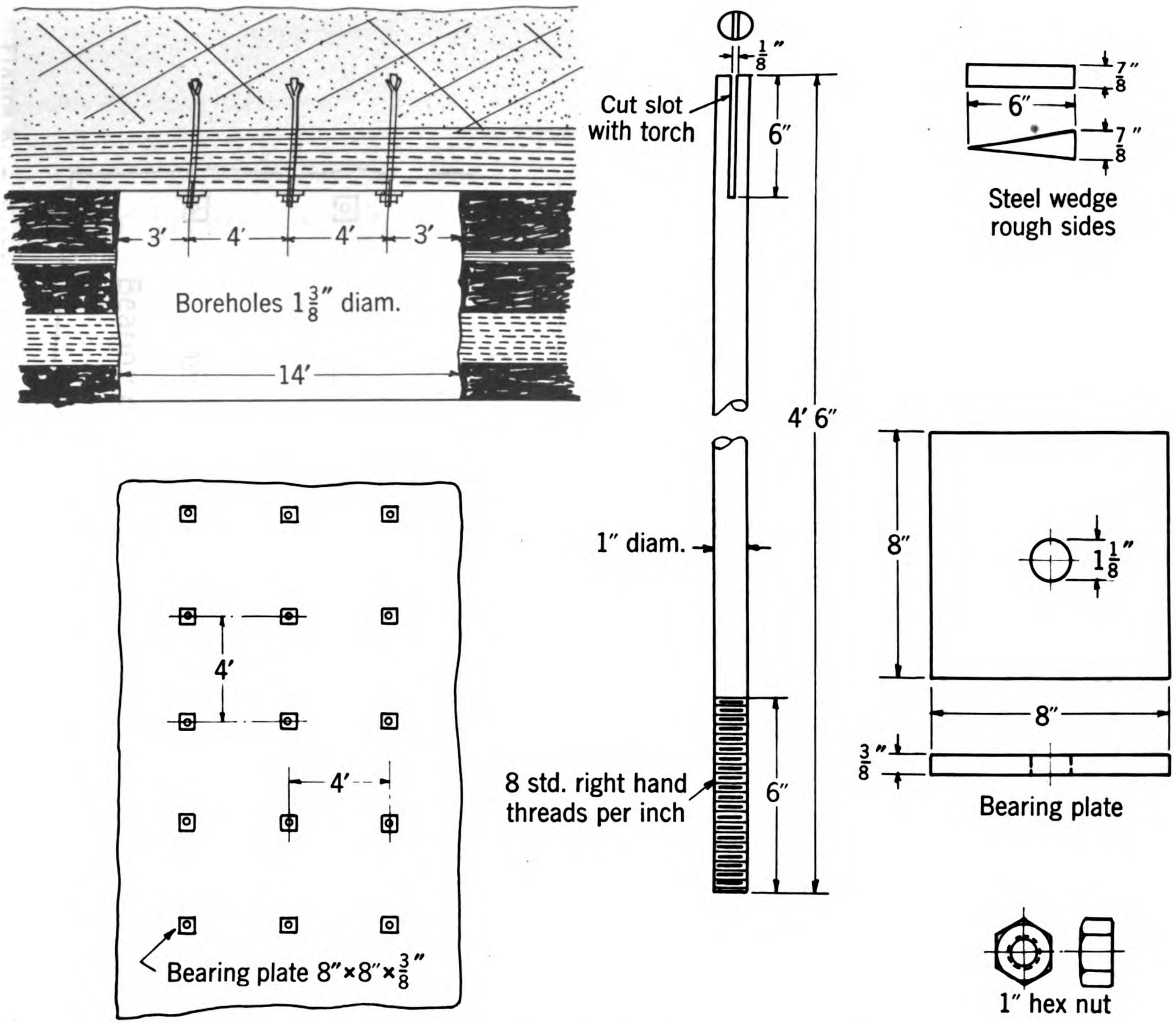

Figure 7. - Suspension support installation.

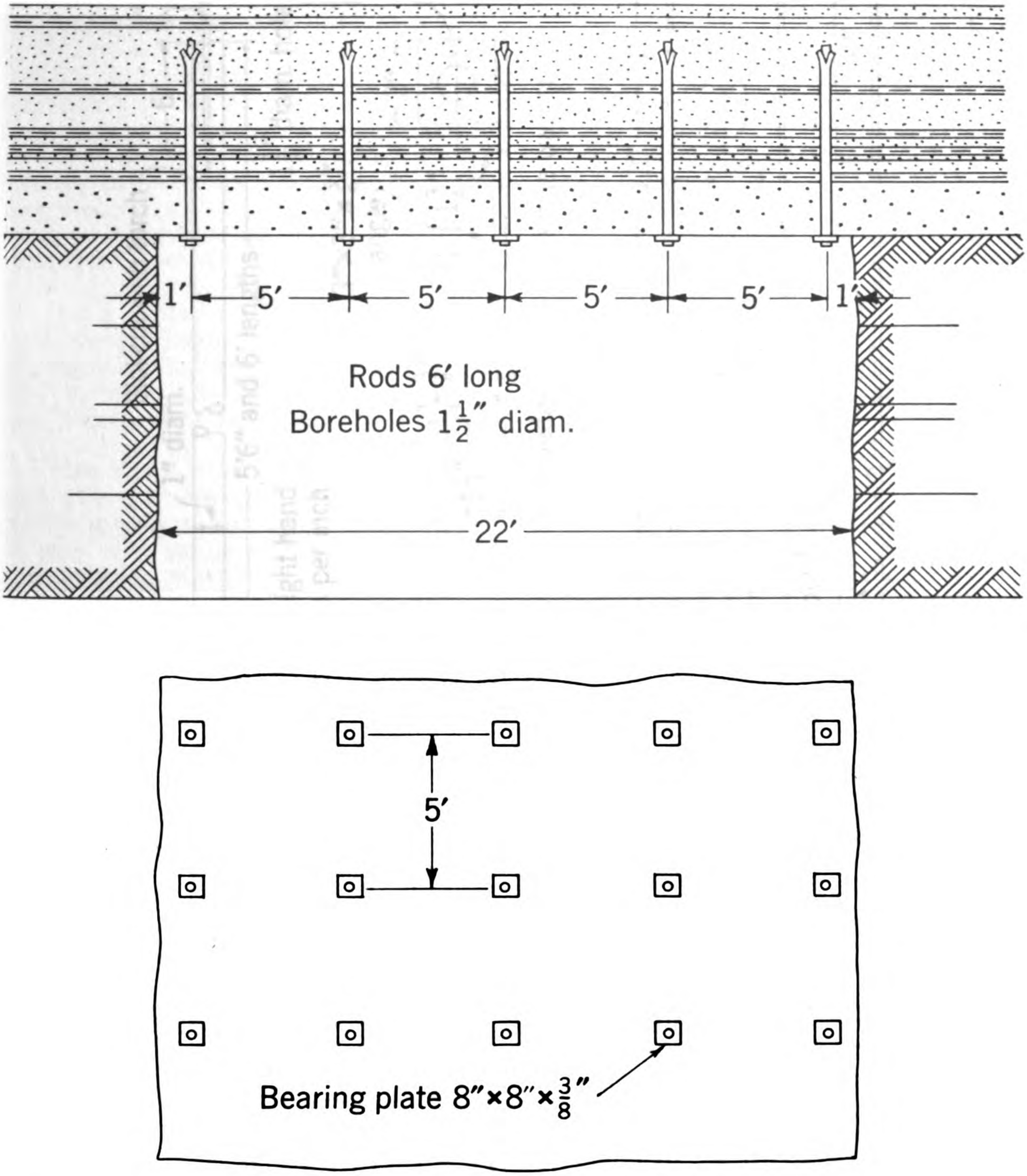

Figure 8. - Suspension support installation. (Details of bolts same as shown in figure 7.)

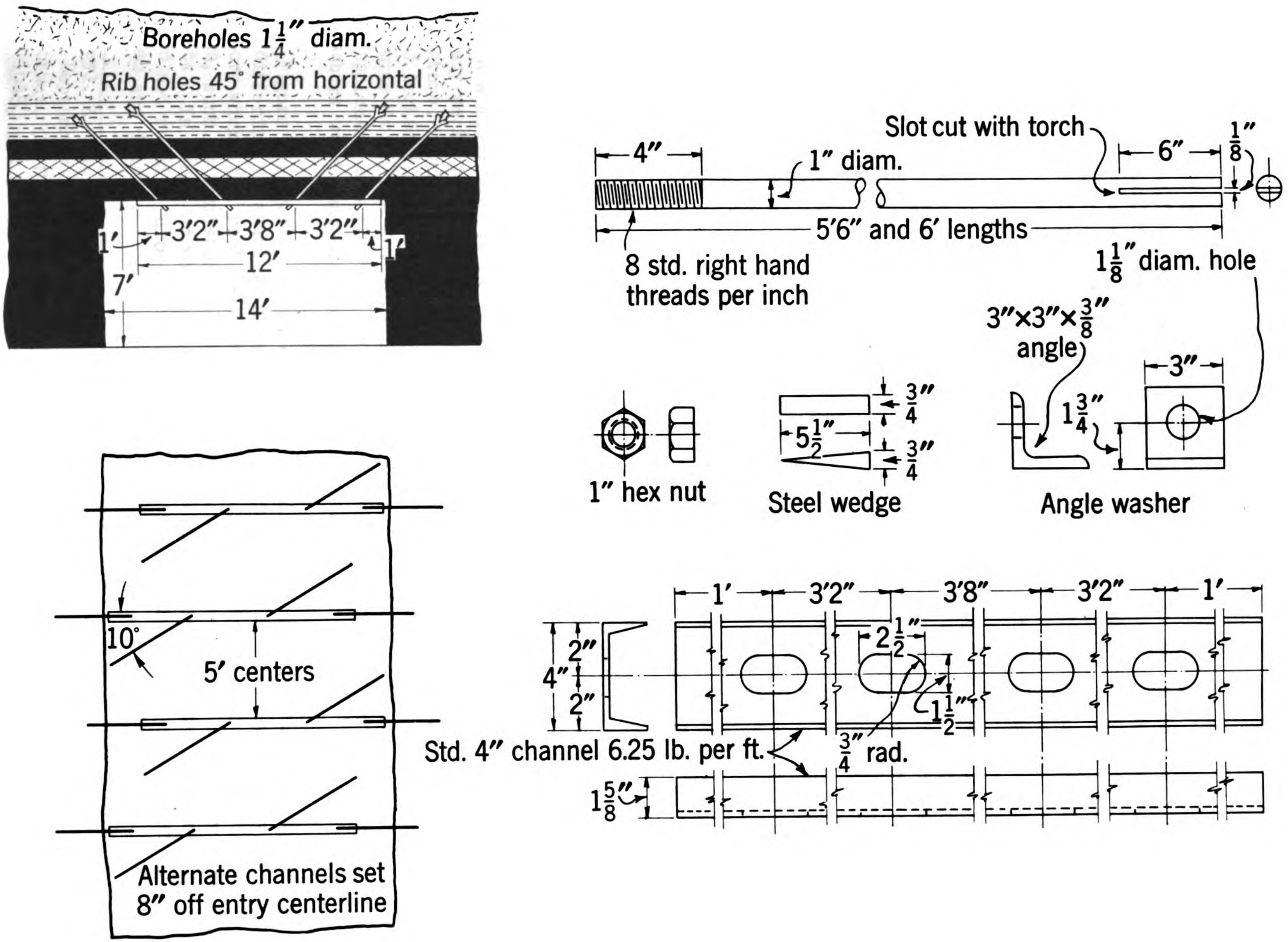

Figure 9. - Suspension support installation.

Lead Co. and was developed during approximately the same period. The principal difference is in the method of anchoring in parts of the mine where soft rock is encountered and anchoring is more difficult. In such places an ingenious device (fig. 5) is used. After a rod is driven over its wedge, a steel tube 8 to 14 inches long and with three-fourths of its length slit by a torch into four strips is slipped over the rod and driven tightly against its wedged end by a sleeve-type driving rod, whereupon the slit tube is deformed and apparently reinforces the soft rock at the back of the holes, decreasing plastic flow.

In a series of articles in Colliery Engineering[7] in 1945 and 1946, Z. S. Beyl, mining engineer of Delft, Holland, proposed a method of supporting roof in longwall mining that incorporated the use of vertical rods with expansion-bolt anchors. Beyl's method, which is patented in the United States, is based upon experiments made in British mines during the war.

The No. 7 mine of the Consolidated Coal Co., Staunton, Ill., was the first coal mine in this country in which experiments were conducted with suspension roof supports as an adjunct to conventional timbering in mechanized mining.[8] At this mine an immediate roof of thinly bedded shale is anchored to a strong main roof of heavily bedded limestone, as shown in figure 6. One-inch rods 18 inches longer than the thickness of the shale are anchored by means of a specially designed expansion shell. An oak bearing plate 1 foot square and 2 inches thick is secured by means of a washer (usually scrap-steel channel sections sawed into 10-inch lengths) and a 1-inch hexagonal nut. These supports are supplemented with wooden posts, particularly in rooms, and sometimes with conventional crossbars. The bore holes are drilled with a standard stoper drill, the rods are anchored, and the nuts are tightened with ratchet-type hand wrenches.

A similar method is shown in figure 7, in which the immediate roof also is very weak, thinly bedded shale overlain with a main roof of heavily bedded sandstone. Rods 1 inch in diameter and 54 inches long are inserted in holes 1-3/8 inches in diameter and 52 inches in depth, drilled on 4-foot centers. The mine is in the development stage, and conventional timbering is not used to supplement the bolting. Prior to the adoption of suspension supports, crossbars were installed on 4-foot centers.

Figure 8 shows a method essentially the same as that shown in figure 7 but differing in spacing of holes and length of rods. This method is satisfactory where the roof is composed of thinly bedded but texturally strong rocks, such as sandstone, limestone, or sandy shale with no pronounced vertical cleats. In other words, borderline cases, where openings, say, 12 feet wide would not require crossbars for support but failure would result when 16-foot places are driven.

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[7] Beyl, Z. S., Rock Pressure and Roof Support: Colliery Eng., 6 pts., September 1945 to October 1946.

[8] Conway, C. C., Roof Support with Suspension Rods: Mining Cong. Jour., June 1948, pp. 32-37.

In one ore mine having a strong but thinly bedded shale and sandstone roof, the roof usually broke when slusher stopes 35 feet wide were driven, even though a row of stulls was maintained in the center of the stopes. When "shin plasters" 6 feet long were installed on approximately 6-foot centers, it was found that the stopes could be widened to 60 feet and yet maintain safe roof conditions. Where rods can be installed vertically, savings in drilling and material costs can be realized.

Some of the most difficult roof-support problems in coal mines in this country, including "cutter" and "snap" roof conditions, have been solved by using four-angled rods with a transverse light channel section (fig. 9). This method closely resembles the St. Joseph Lead Co. practice (figs. 1 and 4), except that the rods are installed at an angle of 45°. This method appears to afford a good measure of safety and at present is being used to initiate many experimental installations.

Figure 10 illustrates a difficult roof condition that was overcome by means of "shin plasters."

Figures 11, 12, and 13 show satisfactory combinations that have been developed experimentally from the basic combination shown in figure 9. From the results obtained it appears that the angled rib holes, many of them, probably, with rods installed at an angle of 55° or more with the horizontal, will provide beam support across openings where vertical cleats are instrumental in weakening the strata. If the immediate roof is strong, a continuous bearing plate usually is unnecessary. Where rods are installed vertically, the holes should not be drilled in longitudinal alinement, because planes of weakness may be developed in the roof strata. The channels support no appreciable vertical load and apparently are incapable of resisting lateral pressure.

TYPES OF ROD INSTALLATIONS

After the length of rod has been determined, the question logically arises, "What type and diameter of rods should be used?" Approximately 95 percent of the rods in use are mild-steel, slit-rod-and-wedge type, 1 inch in diameter. The use of 1-inch rods was not adopted by some companies until after considerable study; some of the factors that influenced acceptance were:

1. In the fabrication of a rod, the amount of material removed therefrom will not reduce its tensile strength appreciably.

2. The rod is rigid enough to permit being driven over the wedge with a percussion drill.

Several types of anchoring devices have been examined and tested in the past year; some have been in common use for many years; some of the newer types may be patentable. Many of these devices are theoretically sound, but most inventors appear to ignore the fact that they must not only equal the time-tested slit-rod-and-wedge type in performance, which is difficult, but must also compete with it in cost. This is especially true of the more

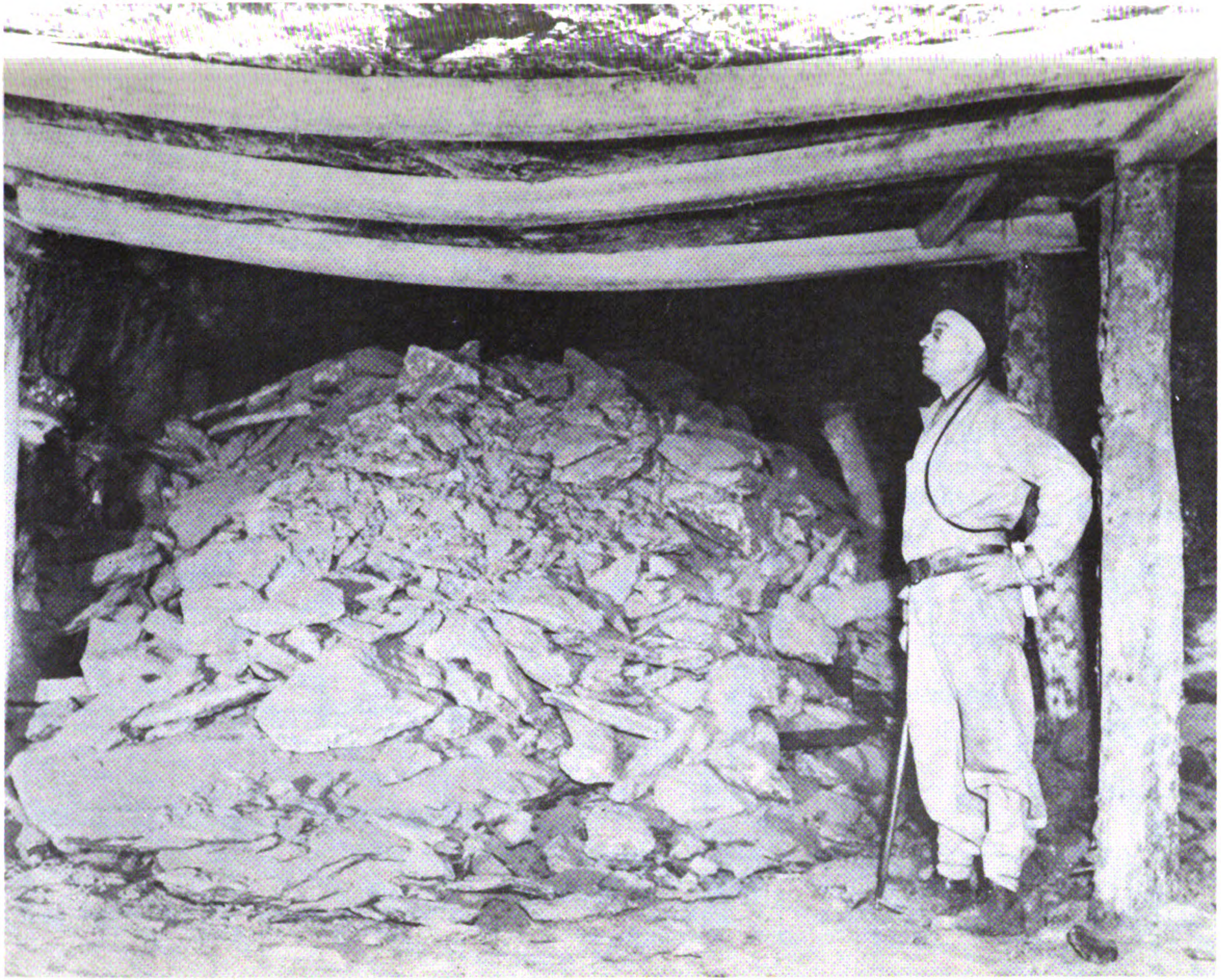

Figure 10. - Difficult roof condition corrected with "shin plasters."

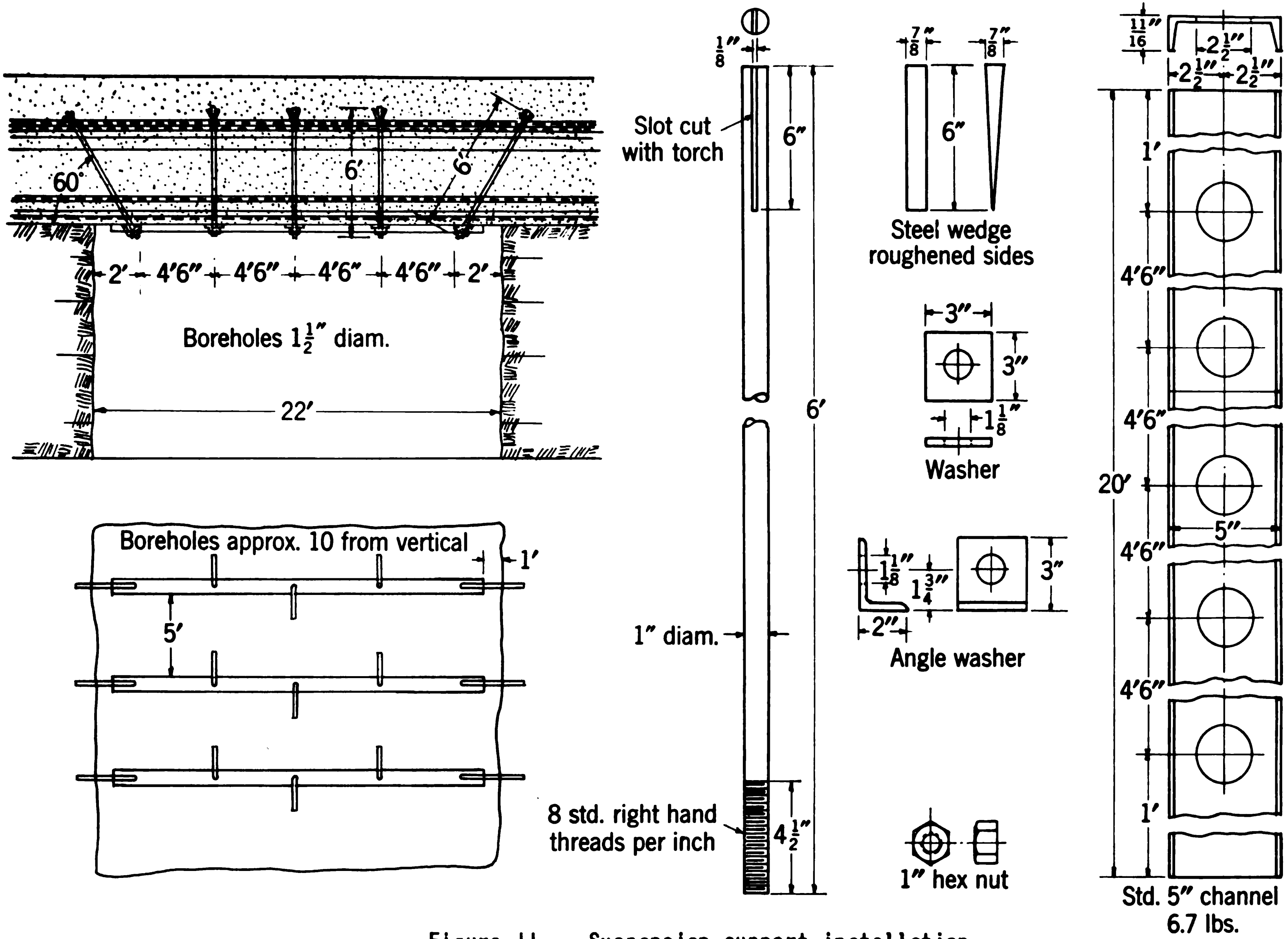

Figure 11. - Suspension support installation.

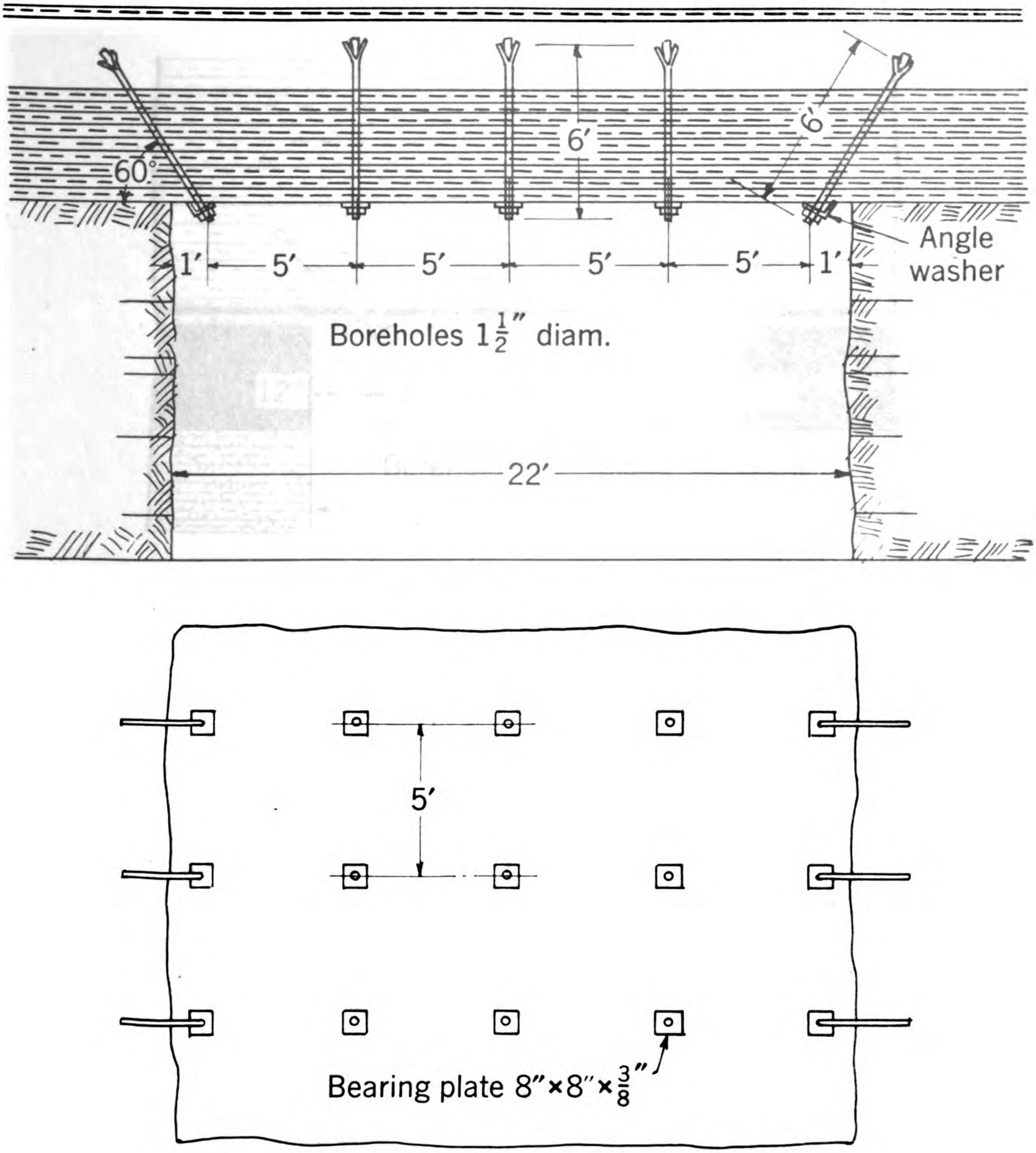

Figure 12. - Suspension support installation. (Details same as figure 11.)

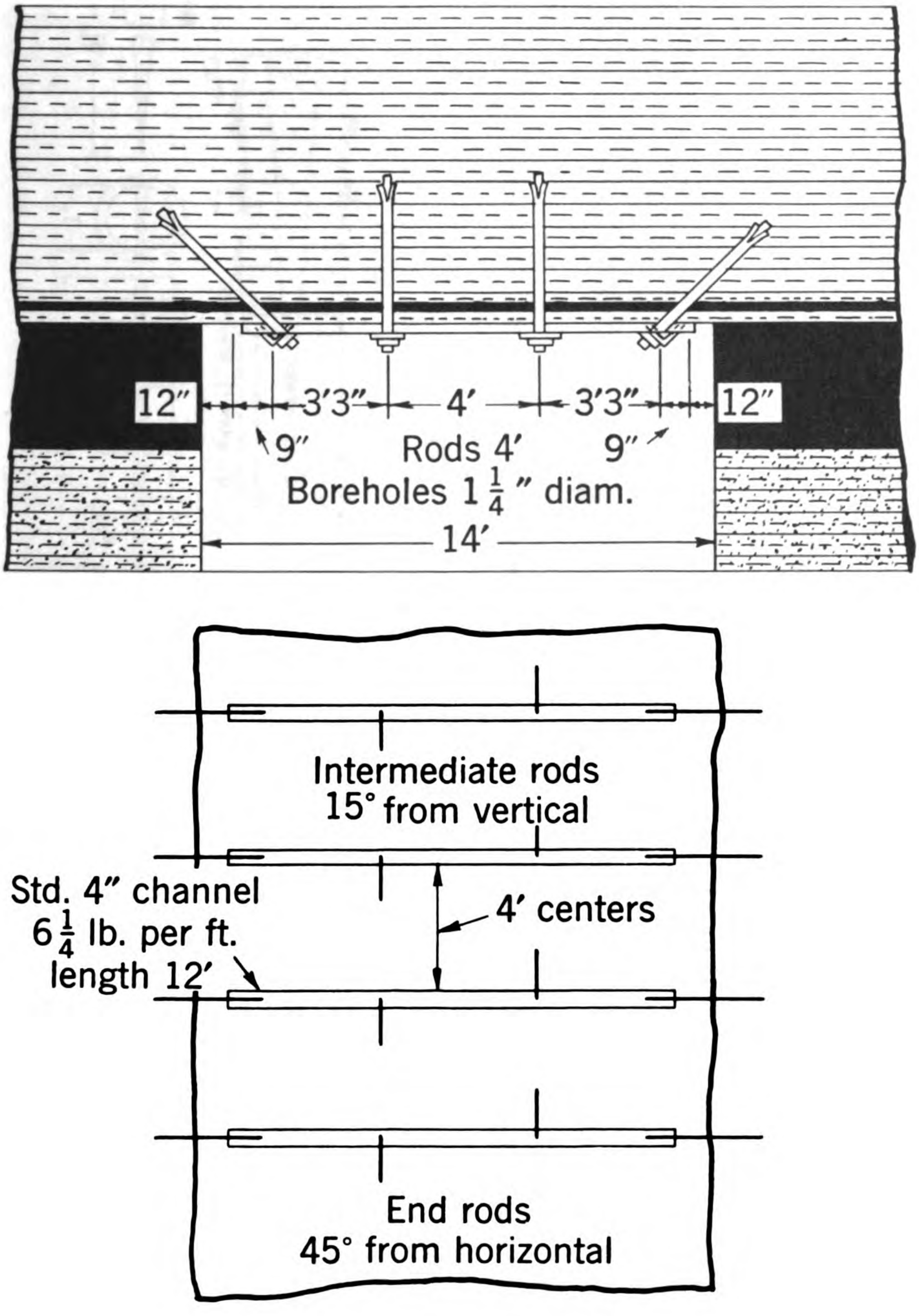

Figure 13. - Suspension support installation. (Details same as figure 9.)

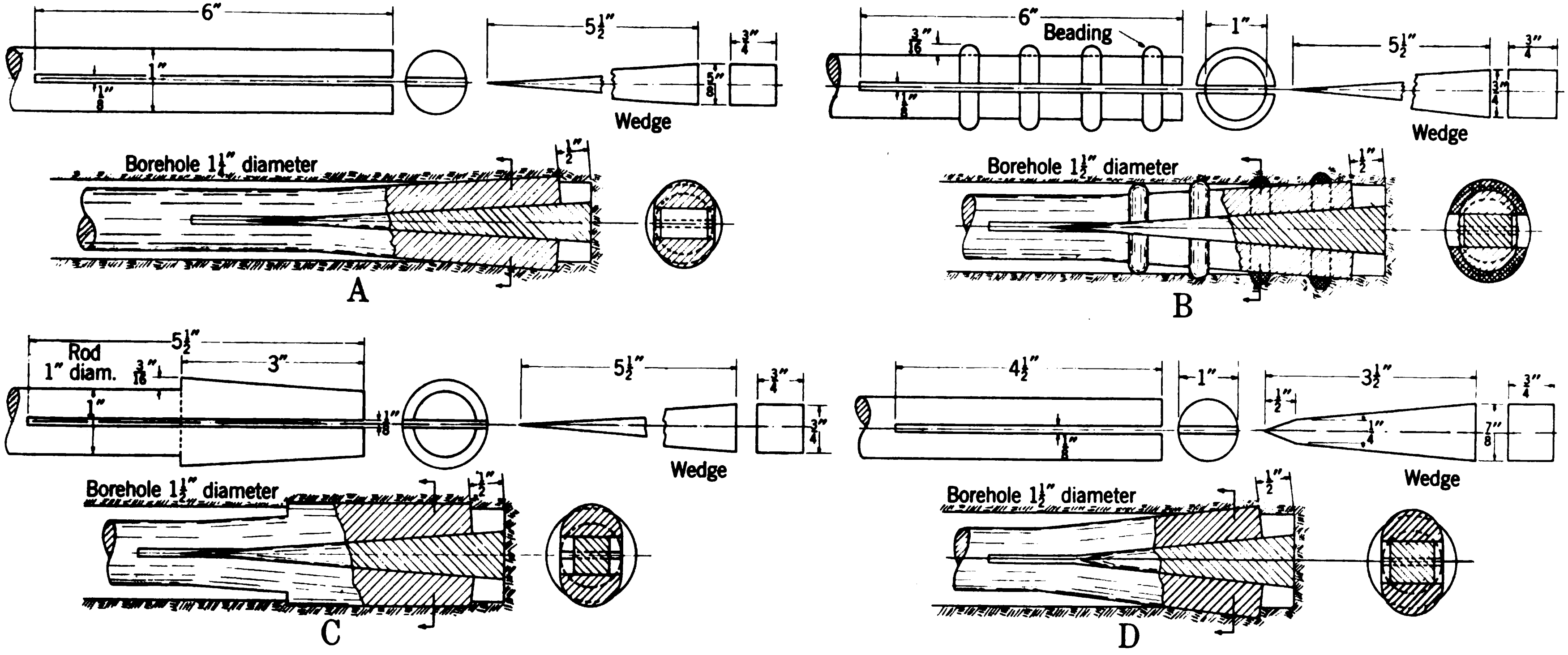

Figure 14. - Types of anchors.

expensive expansion-shell type of anchor. The use of the slit-rod-and-wedge type anchorage, however, imposes a limitation on the minimum diameter of the rod, inasmuch as the slot, whether made with a torch or saw, is approximately 1/8 inch in width and reduces the effective cross-sectional area of a 1-inch rod by approximately 16 percent; whereas, the cross-sectional area of a rod 3/4 inch in diameter is 21.3 percent less than for a rod 1 inch in diameter. No breaks have been reported in the slotted parts of rods in the mines of the St. Joseph Lead Co. or in other mines that have recently adopted a similar practice. However, several failures have been reported wherein rods subjected to excessive loading with sagging strata failed in tension and showed the typical cup-and-ball fracture between the point of anchorage and the bearing plate. As would be expected when a rod is loaded to failure by tightening the nut at the bearing plate, the threads usually will fail before that part of the rod above the threads will yield and fail.

It is doubtful whether decreasing the rod diameter to less than 1 inch would be practicable. More rods would be required to provide comparable support, and the footage to be drilled would be increased; therefore, the only advantage that could be gained in utilizing a rod of smaller diameter might be more than offset by the greater cost of drilling and the greater number of rods required. Conversely, the desirability of increasing the diameter of rod beyond an inch also is doubtful under ordinary circumstances, because in order to justify the additional steel required it will be necessary to increase the distance between adjacent rods and thus increase the flexure of the roof between them.

Until methods are developed to overcome the hazards involved, the Bureau of Mines does not advocate recovery of rods in abandoned workings.

DIAMETER OF HOLES AND SIZE OF WEDGES

Since the Bureau's participation in the program of promoting the use of suspension roof supports it has been believed that clearance of the rod in the hole is important, especially where rods are at an angle with the vertical, for the following reasons: (a) resistance to deflection of the roof beam (constructed by bolting together a number of rock layers) is obtained not only by direct support with the rods but also by resistance to lateral movement of the alternate rock layers, made possible by the bearing of the rod against the sides of the hole; and (b) the less the prongs are spread by the wedge, the greater the bearing area afforded the anchor.

It will be noted that the original successful practice was to drill a 1-1/8-inch-diameter bore hole to receive a 1-inch rod and a wedge 1/2 inch thick at its blunt end (see fig. 4A.). In adapting the suspension supports to other rocks, materials of the same dimensions were used. However, during the past several years carbide-alloy and other special detachable bits 1-1/4 inches in diameter and larger have been developed, with resultant substantial savings in drilling costs, and most operators wish to take advantage of this. The objection is that it appears to be impractical to manufacture and use these bits in diameters smaller than 1-1/4 inches (recent changes in St. Joseph Lead Co. practice are indicated in fig. 4B), and some mining operators prefer 1-1/2-inch bits. Figure 14A illustrates a frequently used combination wherein a 1-1/4-inch borehole is drilled and a 5/8-inch wedge is utilized. When the larger holes are drilled, the following alternatives are presented:

1. Beads may be welded onto the outside of the prongs (fig. 14B) to build up the diameter, or the end of the rod may be forged in the shape of a frustrum of a cone (fig. 14C) with the intent that when the wedge separates the prongs the outside surface of the rod will be parallel to the sides of the hole. The former, though successful in the mines of the St. Joseph Lead Co., has been abandoned for use in shales and sandstones because of the tendency of the rod to "hang up" on one bead. The latter method has been abandoned because of the difficulty in maintaining accurate bit gages.

2. The blunt edge of the wedge can be made thicker; however, this increases the pitch of the wedge, unless a longer slot is made and a longer wedge is used. This is an undesirable expediency because of the great difficulty of maintaining the wedge in the correct position in the slot when the rod is being lifted to the back of the hole. The pitch of the wedge can be maintained without increasing its length by the use of a "stub" wedge (fig. 14D). This type of wedge is used in a few mines, but not enough experience has been gained to justify conclusive statements about it. It should be noted that if the blunt edge is too wide, the resulting angle of spread is likely to weaken the steel at the base of the slot.

BEARING PLATES

It may be inferred from the designs in the foregoing diagrams (figs. 1, 4, 9, 11 and 13) that the purpose of the channel irons or other continuous bearing plates is not to reinforce or supplement the rods but to provide sufficient plate area to prevent spalling from weathering between points where bearing plates are secured. Experience to date appears to indicate that if the immediate roof is reasonably hard, the bearing plate need be only large enough to insure against disintegration of the rock surface when tension is applied to the rods. In several installations 8 by 8 by 3/8-inch steel is used (fig. 15A); at two mines 5 by 8 by 1/2-inch discarded tie plates are used. As shown in figure 6, one company uses a 12- by 12- by 2-inch wood block, and the same company frequently uses full-length wood crossbars as bearing plates at roadway intersections and at room necks. The practice of using wood blocks for the support of roadways having prospective long life is not recommended, because the wood is likely to decay, thus releasing tension in the rods, which in turn permits flexure of the strata. Recently, several companies that use the "shin-plaster" method have adopted the use of triangular bearing plates. These plates are dished to obtain a tripod effect when an uneven roof surface is supported (fig. 15B).

TOOLS FOR ERECTING SUSPENSION SUPPORTS

In a few mines it has been possible to drill holes in the roof with electrically driven rotary drills, and it is reported that at one mine an electrically driven percussion drill is giving satisfactory service; but most mines use pneumatic equipment for drilling holes, anchoring bolts, and tightening nuts. Such use presents no particular problem in most metal mines, which usually are equipped to use compressed air. However, compressed air has not been used extensively in bituminous-coal mines in the past. Pneumatic equipment available in a bituminous-coal mine usually consists of a small portable air compressor that serves not more than one or two light, hand-held drills such as used for grading or drilling for overcasts.

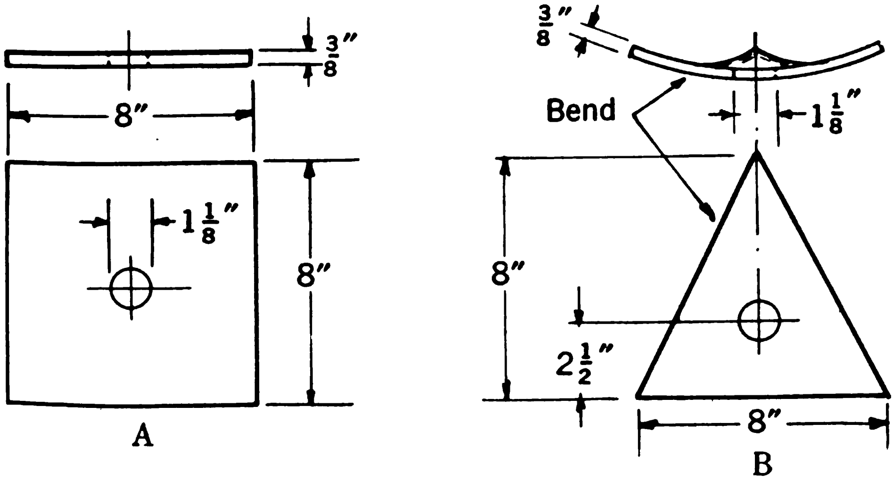

Figure 15. - Bearing plates.

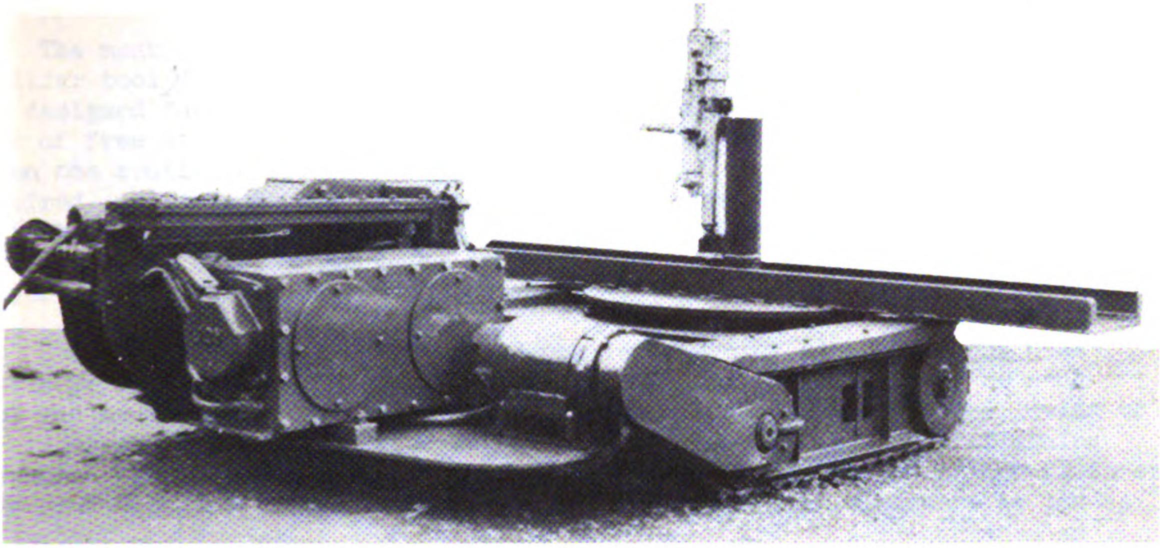

Figure 16. - Mobile drill truck and stoper mount.

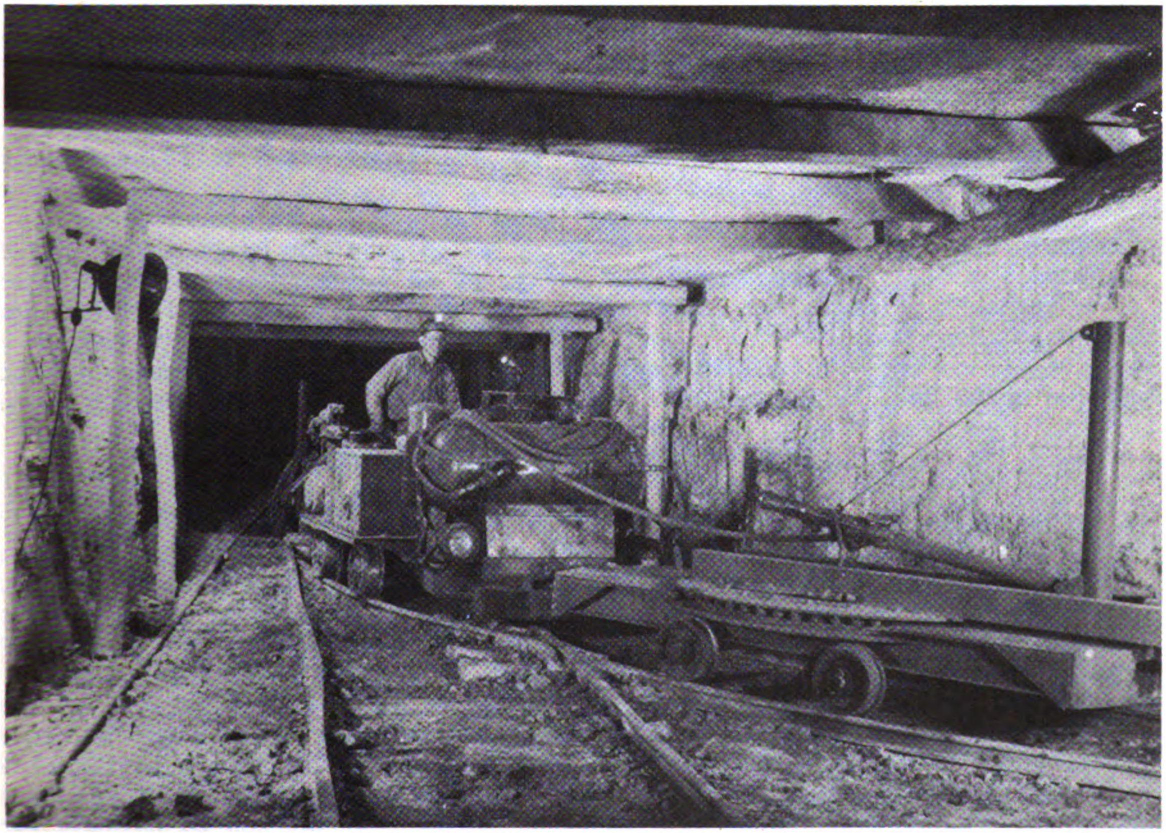

Figure 17. - Mobile compressor and stoper mount.

The most efficient pneumatic drill for "up" holes is the stoper, an unfamiliar tool[9] in most coal mines but commonly used in metal mines. Stopers are designed for high drilling speeds and are rated on the basis of 100 cubic feet of free air per minute at an inlet pressure of 80 pounds per square inch. Often the available portable compressors are not large enough to do the work required, and this is not discovered until the experimental work is under way, so that the job must be delayed until an adequate compressor can be procured. Therefore, the first thing to be done by anyone contemplating a suspension support project is to determine the adequacy of available compressors.

Stoper drills for use where headroom is 5 feet or more have long been available for drilling "up" holes in hard rock, but until recently no such tool was available for use in places with limited headroom. However, owing to the interest in suspension roof supports shown recently by many coal mining companies that operate in thin coal beds, several mining-equipment manufacturers have placed on the market stopers that can be operated in clearance as low as 21 inches.

It has been demonstrated at one large installation that it is possible to tighten the roof-bolt (rod) nuts effectively by means of hand wrenches. However, to obtain uniformity in loading the bolts, by eliminating variations that occur when the nuts are tightened manually by workmen, and to achieve greater uniformity in installation it is desirable that the nuts be tightened with power-driven impact wrenches, and torque meters should be used from time to time to insure that proper tension is being applied to the bolts. Experimental work is underway to develop a standard procedure for tightening nuts, and the results of these tests will be discussed in a future progress report.

Several companies have constructed special drill mounts to facilitate drilling holes at an angle with the vertical (figs. 16 and 17) and equipment manufacturers are contemplating designing and manufacturing various combinations of drill trucks, stoper mounts, compressors, and drilling "jumbos." One company will soon market a combination stoper and impact wrench. A second progress report, planned for early publication, will be devoted to a description of new equipment developed to expedite the erection of suspension supports.

ADAPTATION TO CYCLE OF OPERATIONS

To take full advantage of the suspension roof support, it is necessary to install it at the face as soon as possible after the roof at the face is exposed. It is probable that development of suspension roof supports has lagged because, until recently, mechanization at the face had not advanced sufficiently to justify making large capital investments for the necessary equipment. Such investments would not have been justified with hand-loading methods. Complete mechanization is accompanied by concentration of mining, and because of the increased productivity of small working areas the investment is now justified. This will become increasingly evident with the development and use of continuous-mining machines. However, it should be emphasized that justification is contingent upon the ease with which an installation may be made without interference with normal mining operations.

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[9] For information as to safety and operating instructions, see "How to Operate a Stoper", by A. W. Knoerr: Eng. and Min. Jour., August 1948, pp. 78-83.

In bituminous-coal mining with mobile machines, cutting, drilling, blasting, loading, and timbering usually constitute the cycle of normal mining operations, and up to now no great difficulty has been experienced in installing suspension roof supports in the time alloted to "timbering" if suspension supports are used to supplant conventional crossbars. For efficient use with a continuous-mining machine, it is probable that jumbos will be designed that will permit drilling of roof and installation of supports without the necessity of stopping the continuous machine. In any event, the suspension supports should be installed within a few inches of the face before cutting, and any procedure that delays installation should be discouraged.

Where a portable compressor must be used, it is debatable whether economics can be affected by a self-propelled unit in combination with a jumbo or stoper mount transported to the face for making installations, or whether the compressor should be installed in a semi-permanent location, the compressed air piped to the face, and the compressor later moved forward when the face has advanced approximately 500 feet. In trackless mining, the former will be the most practicable; in sections where the coal is loaded directly into mine cars and possible interference with transportation is a factor to be considered, the latter method probably would be more satisfactory.

INFLUENCE ON METHOD OF MINING

Two limited experiments in the use of suspension supports along pillar lines have been made in mines operating in the Pittsburgh coal bed. Although sufficient data have not been obtained to warrant sweeping conclusions, it was established that the roof bolts (rods) did not interfere with orderly caving. Figure 18 shows channels and rods supporting an entry roof in the Pittsburgh coal bed, which were installed during development of the entry. The bolts consolidated the immediate roof, which broke readily with the main roof when the cantilevered material of the main roof caved (fig. 19). It is particularly desirable to apply this method of support in areas where a great amount of roof-and-floor convergence occurs in the vicinity of pillar lines. Under such conditions, conventional timbering is very costly and often ineffective in preventing the immediate roof from breaking prematurely. Several companies in widely separated localities that are confronted with such a problem are preparing to make large-scale experiments with combinations of roof bolts and rows of conventional wooden breaker posts next to the goaf.

Another indication of the influence of the suspension roof support upon future mining methods may be inferred from the experience at one metal mine. A slabbing method for widening rooms is used at this mine, which has a strong but thinly bedded shale roof, and slusher hoists with scrapers are used to load the ore. When wooden posts or stulls were used for support, it was found that the rooms could be slabbed safely for a total width of only 35 feet, because blasting and the necessity for clearance for the scraper prevented installing enough stulls to support the immediate roof properly. After the suspension roof supports had been adopted in this mine, an experimental room 200 feet long was slabbed to a width of 110 feet before failure occurred.

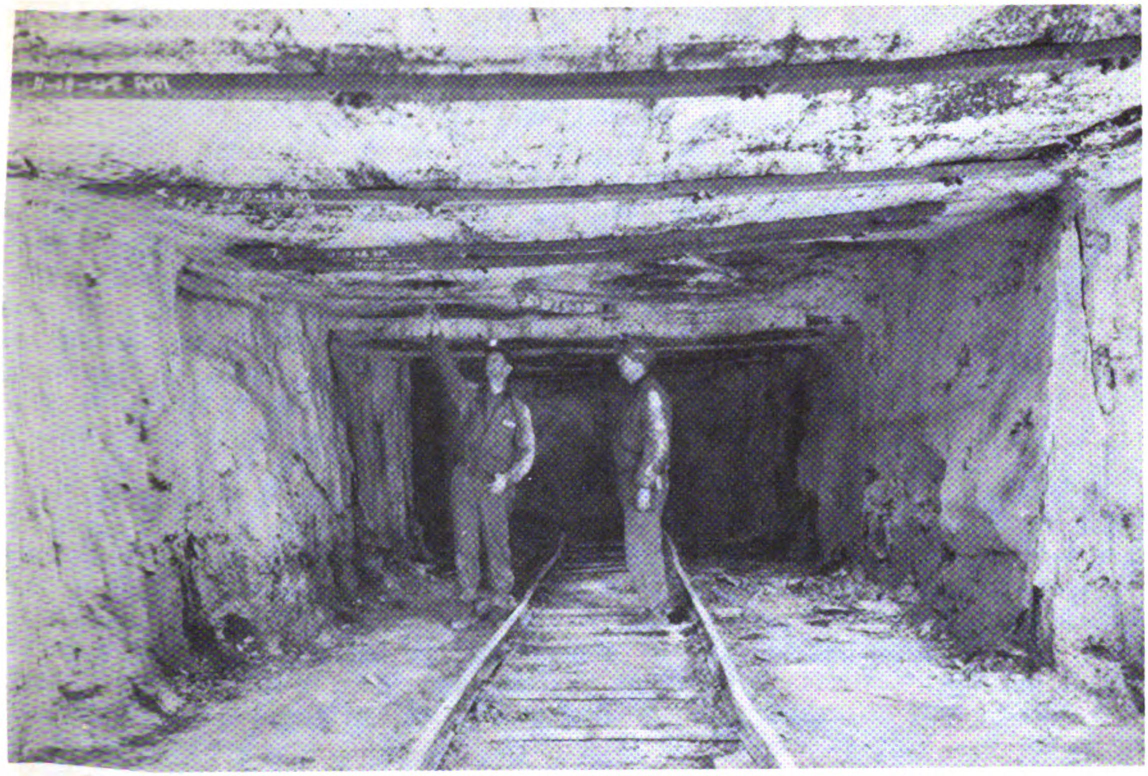

Figure 18. - Channels and rods supporting entry roof.

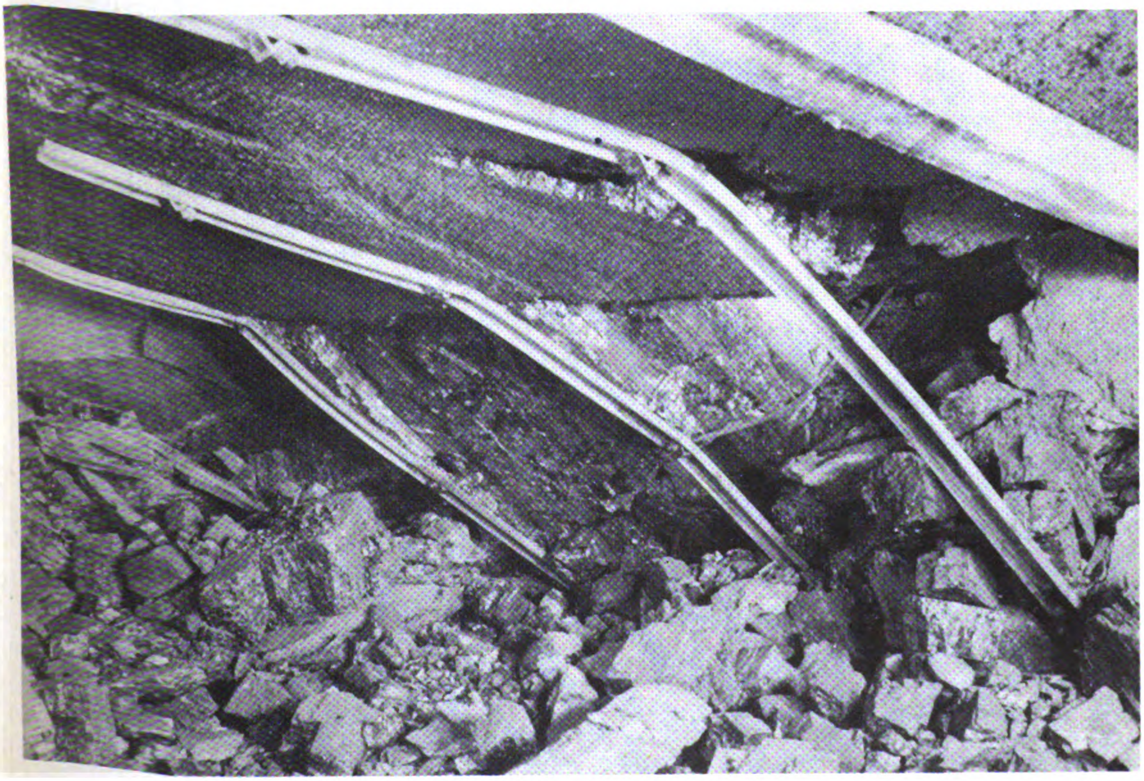

Figure 19. - Pillar-extraction experiment.

CONCLUSIONS

Suspension roof support offers the mining industry a safe, efficient method of roof support. The method has been applied extensively under widely different roof conditions and affords the possibility of developing new and more efficient methods of mining. Many questions regarding the theory and application of this type of support cannot be answered definitely as yet. Present knowledge indicates that it is not a "cure-all" for all types of roof conditions, nor can a method that is successful in one mine be assumed to be safe for another without careful study and closely supervised experimentation under controlled conditions.

The Bureau of Mines, in cooperation with several mining companies and State agencies, is carrying on a program of research and investigation not only on problems involving suspension-roof supports, but also on the broader subject of roof control in general. As part of this program, one or more Bureau specialists in roof control have been assigned to each district and subdistrict office of the Coal Mine Inspection Branch, Health and Safety Division, Bureau of Mines. These men may be consulted by applying to the supervising engineer of the nearest district office or the engineer-in-charge of the nearest subdistrict office.